Check 21. Developing Smart Telehealth System.pdf

by Arta Sundjaja

Submission date: 06-May-2019 10:47AM (UTC+0700)
Submission ID: 1102510710
File name: 21._Developing_Smart_Telehealth_System.pdf (1.49M)
Word count: 4371
Character count: 24093

[Invited Paper]

Developing Smart Telehealth System in Indonesia : Progress and Challenge

W. Jatmiko[1], M. Anwar Ma'sum[1], Sani M. Isa[1], E.M. Imah[1], R. Rahmatullah[1], Budi Wiweko[2]
[1]Faculty of Computer Science Universitas Indonesia, [2]Faculty of Medicine, Universitas Indonesia
Email : wisnuj@cs.ui.ac.id

***Abstract*— Indonesia is developing country with high population. There are more than 200 million residents living in the country. As a developing country, Indonesia has several health problems. First, Indonesia has a high value of mortality caused by heart and cardio vascular diseases. One of the major cause is the lack of medical checkup especially for heart monitoring. It is caused by limited number of medical instrumentation e.g. ECG in hospital and public health center. The supporting factor is the small number of cardiologist in Indonesia. There are 365 cardiologists across the country, which is a very small number compared to the 200 million of Indonesia population. Furthermore, they are not distributed evenly in all provinces, but only centered in Jakarta and other capital cities. Therefore, it is difficult for residents to get appropriate heart monitoring. Second, the mortality rate of mother and baby during delivery of the baby in Indonesia is also high. One way to solve this problem is to devise a system where the health clinics in rural areas can perform fetal biometry detection before consulting the results to the expert physicians from other areas. The proposed system will be equipped with algorithms for automatic fetal detection and biometry measurement. By the end of this development, we have several results, the first is a classifier to automatic heartbeat disease prediction with accuracy more than 95%, the second is compression method based on wavelet decompositon, and the third is detection and approximation a fetus in an ultrasound image with hit rate more than 93%.**

Keywords*—*telehealth; ECG; USG; Heart Disease; Feal Growth;

I. INTRODUCTION

Indonesia is a developing country with high population number. There are more than 200 million residents living in the country. As a developing country, Indonesia has several health problems. First, Indonesia has a high value of mortality caused by heart and cardio vascular diseases. One of the major cause is the lack of medical checkup, especially for heart monitoring. It is caused by the limited number of medical instrumentation e.g. ECG in hospitals and public health centers. The supporting factor is the small number of cardiologists in Indonesia. There are 365 cardiologists across the country which is a very small number compared to the 200 million of Indonesia population. Furthermore, they are not distributed evenly in all provinces, but centered in Jakarta and other capital cities. Therefore, it is difficult for residents to get appropriate heart monitoring.

Meanwhile, Indonesia also has similar problem in other health area. High number of fetal and maternal mortality becomes a serious problem. Annual fetal mortality rate as of 2011 is 34 per 1000 birth, whereas maternal mortality rate is 10 per 1000 birth according to the Ministry of Health Republic Indonesia. One of the major factor is the lack of fetal growth monitoring. It is caused by limited number of USG device and Obstetricians. Therefore, fetal growth monitoring is needed in order to help pregnant mothers to monitor their fetus.

Based on these facts, we have developed a smart telehealth system In Indonesia. The development is focused on tele-ECG system, and tele-USG system. Tele-ECG system have been built for heart diseases early detection and monitoring system. Tele-ECG system has three main components. There are ECG sensors, PC or smartphone, and server. The ECG sensors are used to acquire heartbeat signal from patient. After being recorded, the signal will be processed. Then, the signal can be classified to predict the patient condition automatically, whether it is normal or has heart diseases symptoms. Next, the signal is sent to the server to be verified by cardiologists.

Tele-USG is developed to monitor fetal growth. The main function of the tele-USG system is automatic fetal biometric measurement and detection of fetal growth disorder. The system have three main components, they ar smartphone and server. In Tele-USG system, we have not develop hardware yet, due to complexity of the USG sensor. In this system we use ultrasound image captured from conventional USG devices. Software installed in patient smartphone is used to monitor fetal growth. More detail explanation about tele-ECG and tele-USG system is written in section 2.

There are several related works that we have conducted to develop the telehelath system. Sudhamony et al developed telehealth system for cancer-care delivery in India [1]. Garawi et al developed 3G wireless communications for mobile robotic tele-ultrasonography systems [2]. The other works were focused on several subsets of telehealth system. Hababeh et al designed a High Performance Web-Based Computing Services to Promote Telemedicine Database Management System [3]. In the previous study, we have been developed a tele-ECG system. The Tele-ECG system is equipped with automatic prediction for health diseases. For automatic prediction feature, The system used neural classifier algorithm as proposed by Imah et al [4]. The tele-ECG system is also equipped with data compression feature. The data compression algorithm used is proposed by Isa et al [5]. In the previous study we have also

 978-1-5090-0363-1/15/$31.00

developed tele-USG system for fetal growth monitoring [6]. This tele-USG system is equipped by automatic fetal biometrics measurement features. The algorithm for biometrics computing is proposed by Ma'sum et al [7]. This paper discusses the development of smart telehealth system in Indonesia. More specific topic discussed in this paper is the progress and challenge of tele-ECG and tele-USG development. The discussion includes the architecture of the telehealth system, signal processing, algorithms, and performance evaluation.

Telehealth architecture, and components is written in section 2. Section 3 discusses signal processing conducted on telehealth. Performance evaluation of telehealth system is discussed in section 4. Section 5 discusses the future challenge of telehealth systems in Indonesia. Section 6 drwas the conclusion of the paper.

II. Telehealth System

A. Tele-ECG System

Tele-ECG system architecture is shown in fig. 1. As shown in the figure, tele-ECG has three main components. The first component is ECG sensor that is used to capture human heartbeat, the second component is smartphone and the third component is the server. Generally, a smartphone is used to process the heartbeat signal. The goal of the signal processing is to classify the heartbeat signal and send it to server. Server is used to save patient heartbeat signal as cloud storage. The other function of the server is to connect patients and doctors.

1) ECG Sensor

In this research, we have developed two versions of ECG sensors. One of them is single lead ECG, and the other is 12-lead ECG sensor. ECG sensor consists several types of hardware. There are electronic ECG sensor, microcontroller, bluetooth module, power supply (battery) and other electronics components. The electronics ECG sensor used in this research consists of amplifier circuit, low pas filter circuit, high pass filter circuit, and adder circuit. The sensor can amplify heartbeat signal up to 1000 times. The input signal captured from human body is between 1-4 mV, and the output signal of the sensor is between 1-4 V. The microcontroller is used to convert analog signal to digital signal using its ADC feature. Then it sends the converted signal to smartphone. To capture the heartbeat signal, smartphone and microcontroller use bluetooth network. Therefore, It need bluetooth module to be attached to microcontroller.

2) Smartphone

In tele-ECG system, smartphone is used to visualize, save, and classify heartbeat signal, and send it to the server. Before classification, the signal must be preprocessed first. The preprocessing includes baseline wander removal, beat segmentation and normalization, and wavelet. After being classified, the signal will be sent to the server to be verified by a cardiologist. Before sent to server, the signal must be compressed. Compression is used to reduce signal size and encrypt the signal data. Detail of these signal processing method is explained in section 3. To implement these main features, there are several menus on smartphone application. There are "User management", "Heartbeart History", "Retrieve Signal from Sensor", "Classify", "Verify Heartbeat" etc. The application is made for user and officer to conduct those functions directly using ECG sensor.

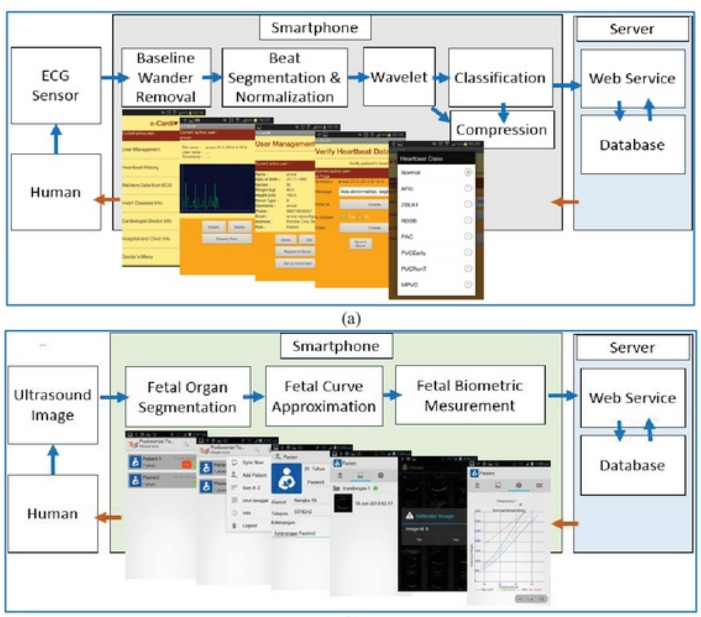

Fig. 1. Tlehealth System Architecture (a) Tele-ECG (b) Tele-USG

3) Server

The third component on tele-ECG system is server. As mentioned before, the main function of the server is cloud storage of the system. Server is used to save heartbeat data coresponting to its user (patient). The other main function of server is to connect patients and cardiologists. The prediction generated by system need to be verified by doctors. Therefore, heartbear data must be sent to the doctors. To implement these two main features, server has web service and database.

B. Tele-USG System

Tele-USG system architecture is shown in fig. 1. The Tele-USG has two main components. The first component is ECG sensor that used to capture human heartbeat, the second component is server. In tele-USG we have not developed ultrasound sensor. Ultrasound image is used as input in the tele-USG system

1) Smartphone

Generally, the tele-USG system smartphone is used to monitor fetal growth. Smartphone is also equipped with automatic fetal biometric measurement feature. The feature is to help the user measure fetal organ size. To implement these main features, there are several menus on the smartphone application. There are "User management", "Pregnancy History", "Add ultrasound data", "Automatic Measurement", "Fetal Growth Curve", "Doctor Evaluation", "Consultation" etc. The application is made for user officer in the hospital or public health center. Each smartphone can be used to monitor multiple patients (pregnant mother)

2) Server

The second component in tele-USG system is server. The functions of this component is the same as in tele-ECG. They are cloud storage for pregnancy data of the patients and connector between patients and doctor.

III. DATA PROCESSING

A. Tele-ECG System

Data processing on Tele-ECG system is shown in fig. 1. The signal processing includes baseline wander removal, beat segmentation and normalization, wavelet, classification and compression.

1) Baseline Wander Removal

The first phase of the ECG signal processing is Baseline Wander Removal (BWR). Baseline is a condition where the signal has axes disorder as shown in Fig.2 (top). This phenomenon is caused by noise signal came from human body. The noise signal can be generated by respiratory activity in human body or human movement during examination. This curve disorder can cause error detection during classification process. Therefore, It is important to repair the signal to be isoelectric as shown in fig.2 (bottom).

BWR process is a non linier cubic interpolation using spline combined with reduction method. Therefore, it can reduce noise without changing waveform of ECG signal. The basic idea of BWR is estimating shift amount using sampling points. The sampling points are representatives from the beats of ECG signal. Each point represents each beat of the signal. Cubic interpolation is used because it can smoothen the signal. Furthermore, it guarantees the continuity of its first and second derivatives at the entire interval. In this research, BWR method used was originally proposed by Clifford et al [8].

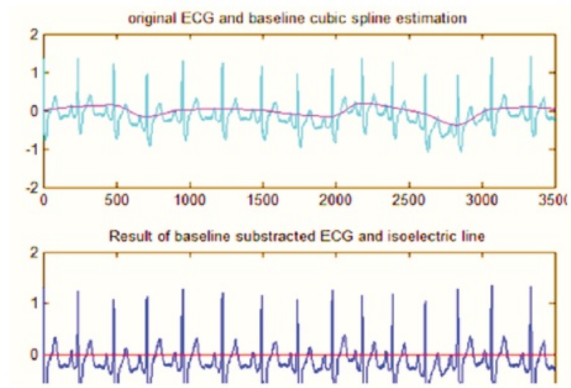

Fig. 2. Baseline Wander Removal Process

2) Beat Segmentation and Normalization

After being repaired by the BWR process, the signal is segmented into beats. Beat segment is conducted using R-R detection algorithm. Fig 3. shows the result of the beat extraction. After the beat extraction process, the signal values are normalized from integer to floating point format. The normalized values is lies between -1 and 1. Normalization is important because next operations use floating point number format.

Fig 3. Rsult of beat extraction

3) Wavelet

The third step is wavelet process. Wavelet process is used for data dimentionality reduction. In this telehealth system, each heart beat signal consists of 850 points. The system needs to reduce the data size in order to speed up the computation. Therefore, wavelet is used to simplify the size of the signal. This tele-ECG system uses 4 degree wavelet. Therefore, the heart beat signal is reduced up to $850 / (2^4) \approx 55$ points. This tele-ECG systems use Daubechies 2 kernel for wavelet process.

Daubechies 2 is chosen because among wavelet kernel, its waveform is the most similar to ECG signal.

4) *Classification*

As mentioned in previous sub section, the Tele-ECG systems has an automatic heart diseases prediction. For the prediction feature, it uses Adaptive Mahalonobis Generalized Learning Vector Quantization (AMGLVQ) proposed by Imah et al [4]. The architecture of AMGLVQ is shown in fig 4.

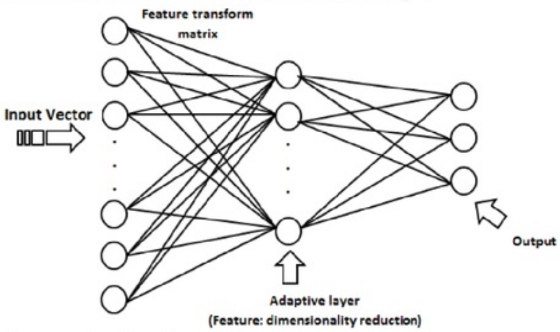

Fig. 4. AMGLVQ architecture[4]

In AMGLVQ, input vector is denote as *x*. Input data in eigen space is denoted as *x'* defined as written in equation below.

$$x' = T^T x \qquad (1)$$

Therefore we need to find best value of transformation matrix T during training process. Update rule for matrix T is defined as written in equation below.

$$T^T{}_t \leftarrow T^T{}_{t-1} + \alpha \frac{\delta f}{\delta \varphi} \frac{4d_2}{(d_1 + d_2)^2} (T^T x - T^T w_1)(x - w_1) \qquad (2)$$

$$w_1 \leftarrow w_1 + \alpha \frac{\delta f}{\delta \varphi} \frac{4d_2}{(d_1 + d_2)^2} (T^T x - T^T w_1) \qquad (3)$$

$$w_2 \leftarrow w_2 - \alpha \frac{\delta f}{\delta \varphi} \frac{4d_1}{(d_1 + d_2)^2} (T^T x - T^T w_2) \qquad (4)$$

Where w_1 the nearest reference vector that belongs to the same class of *x*. Likewise, let w_2 be the nearest reference vector that belongs to a different class from x.

5) *Compression*

Compresiion is used to compress heartbeat data before transmitting it to the server. This telehealth system uses 2D-SPIHT compression algorithm. The flow of 2D-SPIHT is shown in fig.5. There are two steps, encoding process and decoding process. The input of the encoding process is preprocessed signal which is produced from beat segmentation and normalization process. Then the beats of the signal are reordered. The next process is signal transformation using wavelet. The last step is encoding. The decoding process starts with signal decoding using SPIHT. Then the signal is transformed using inverse wavelet. Then beats of the signal is unordered and transformed from 2D array to 1D array. The last step is denormalization to gain original signal.

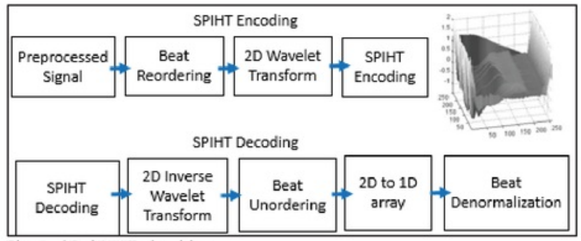

Fig. 5. 2D-SPIHT algorithm

B. *Tele-USG System*

Data processing on Tele-ECG system is shown in fig. 1. The processes include fetal organ segmentation, fetal organ approximation, and fetal biometric measurement.

1) *Fetal Organ Segmenttion*

In this study, fetal organ segmentation is done by detecting fetal organ boundary box as shown in fig.6. Fetal organ detection uses supervised approach using boosting ensemble classifier based on stump weak classifier. For fetal organ detection, we have made training sample by cropping fetal organ from ultrasound images. Then the instances are used to training the classifier. In this study, the classifier used haar feaures generated from training samples.

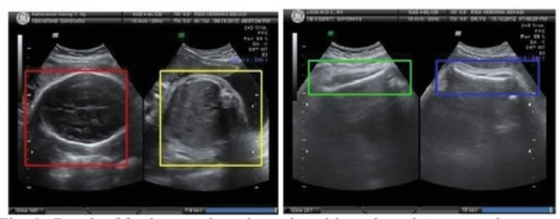

Fig. 6. Result of fetal organ detection using object detection approach

2) *Fetal Organ Approximation*

After being segmented, then the curve of fetal organs is approximated using Hough Transform based approximation. Fetal head and abdomen are approximated by ellipse curve, whereas fetal femur and humerus are approximated by line curve. In Cartesian coodinate (x,y), a line can be described using this following equation:

$$y = mx + n \qquad (5)$$

Where m is gradient (slope line) and n is the offset of the line on y-axis. A point (y_k,x_k) can be represented in Hough space as defined in the following equation:

$$m = \frac{y_k}{x_k} - \frac{1}{x_k} n \qquad (6)$$

The basic idea of ellipse curve approximation is ftting ellipse equation defined as follows

Where a and b is the semi-major and semi-minor axis of the ellipse, and (x_c, y_c) is the center point of the ellipse. Ellipse equation (7) can be written as follows:

$$\frac{(x\cos\theta + y\sin\theta)^2}{a^2} + \frac{(x\sin\theta - y\cos\theta)^2}{b^2} = 1 \quad (8)$$

To determine the ellipse parameter, the previous ellipse equation is modified into following formula:

$$x^2 + y^2 - U(x^2 - y^2) - 2Vxy - Rx - Sy - T = 0 \quad (9)$$

Each variable on equation (8) is computed using the following set of equations:

$$e = \frac{b}{a} \quad (10)$$

$$U = \frac{1-e^2}{1+e^2}\cos 2\theta \quad (11)$$

$$V = \frac{1-e^2}{1+e^2}\sin 2\theta \quad (12)$$

$$R = 2x_c(1-U) - 2y_cV \quad (13)$$

$$S = 2y_c(1-U) - 2x_cV \quad (14)$$

$$T = \frac{2a^2b^2}{a^2+b^2} - \frac{x_cR}{2} - \frac{y_cS}{2} \quad (15)$$

Ellipse parameters [a, b, x_0, y_0, θ] can be extracted using following set of equations.

$$x_0 = \frac{SV + R + RU}{2(1-U^2-V^2)} \quad (16)$$

$$y_0 = \frac{RV + S - SU}{2(1-U^2-V^2)} \quad (17)$$

$$a = \sqrt{\frac{2T + x_0R + y_0S}{2\left(1-\sqrt{U^2+V^2}\right)}} \quad (18)$$

$$b = \sqrt{\frac{2T + x_0R + y_0S}{2\left(1+\sqrt{U^2+V^2}\right)}} \quad (19)$$

$$\phi = \frac{1}{2}\arctan\frac{V}{U} \quad (20)$$

In this study, there are several variations of Hough transform used. There are Randomize Hough Transform (RHT), Iterative Randomize Hough Transform (IRHT), and Eliminating Particle Swarm Optimization Hough Transform (EPSO-HT) [8][9][10]. The result of fetal organ approximation is shown in fig. 7.

3) Fetal Biometric Measurement

The last step of ultrasound image processing is fetal biometric measurement. From fetal head image, the system computes head circumference (HC), and biparietal diameter (BPD). From fetal abdomen, the system computes abdomen circumference (AC). From fetal femur and humerus, the system computes femur length (FL) and humerus length respectively (HL). HC and AC are computed from ellipse circumference. BPD is computed from ellipse minor axis. FL and HL are computed from length of the line curve.

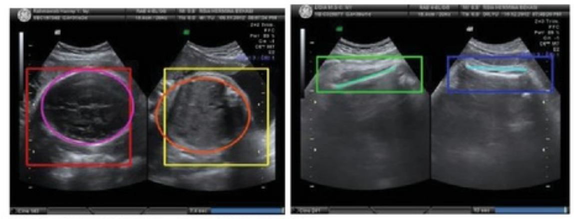

Fig. 7. Result of fetal organ approximation

IV. PERFORMANCE EVALUATION

A. Tele-ECG System Performance

On Tele-ECG system, there are several evaluations conducted. The first evaluation is classifier accuracy for automatic heartbeat prediction and compression error.

1) Classifier Accuracy

For classifier evaluation, we used MIT-BIH Arrhythmias dataset [11]. There are 14 classes on the database. They are Normal Beat (NOR), Left Bundle Branch Block beat (LBBB), Right Bundle Branch Block beat (RBBB), Premature Ventricular Contraction beat (PVC), Paced beat (P), Atrial Premature beat (AP), Fusion of Ventricular and Normal beat (fVN), Fusion of Paced and Normal beat (fPN), Nodal (Junctional) Escape beat (NE). Aberrated Atrial Prematur beat(aAP), Ventricular Escape (VE), Nodal (junctional) Premature beat (NP), Arial Escape beat (AE), and Supra ventricular Premature beat (SP).

In this evaluation, we used two variation scenarios. The first scenario is conducted without unknown class, whereas the second scenario is conducted with unknown class. In this evaluation AMGLVQ is compared to existing methods. The comparators are LVQ, GLVQ, Backpropagation, and SVM [12]-[15]. The experiment result is shown in fig 8. For both scenarios, AMGLVQ has highest accuracy among all. AMGLVQ reaches 95,16% and 95,04% accuracy for scenario 1 and scenario 2 respectively.

2) Compresion Error

For compression evaluation, we used percentage root-mean-square difference (PRD). In this evaluation 2D-SPIHT is compared to existing methods. PRD values of the compression algorithm are shown in table 1. Table 1 shows that 2D-SPIHT has the lowest PRD for those two variation of compression ratio. The PRD of 2D-SPIHT is less than 3.0 whereas PRD of the other methods are higher than 3.

B. Tele-USG System Performance

Fig. 8 shows the hit rate of fetal organ approximation of various methods. For head and abdomen organ, the methods used are Detection+RHT, Detection+IRHT, RHT, IRHT, and EPSOHT. For femur and humerus, the methods used are

Detection+PHT, Detection+RHT, Detection+IRHT, RHT, and IRHT. Detection+PHT method is not used in head and abdomen approximation. The same applies to EPSOHT in femur and humerus approximation.

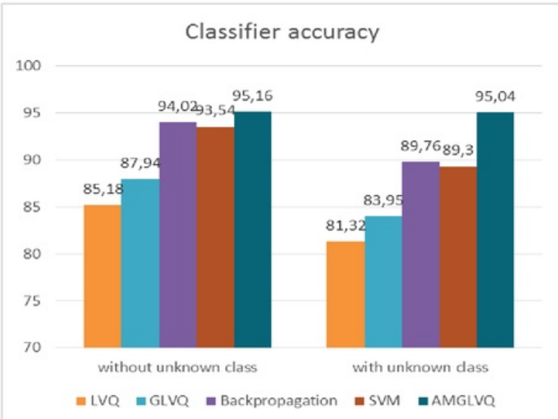

Fig. 8. Classifier Performance

Detection+RHT achieves the highest hit rate for head approximation with 0,95 while Detection+IRHT scores 0,93. For abdomen approximation, both Detection+RHT and Detection+IRHT scores 0,92 and 0,93 respectively. Detection+PHT scores the highest hit rate for both femur and humerus approximation with 0,97 in both approximation

Table 1 Compression PRD

Compression Algorithm	CR	PRD
2D-SPIHT	13	2,49
	16	2,82
Benzid[16]	12,6	3,51
	15,95	4,84
Lu[17]	12	3,57
	16	4,85
Blanco[18]	11,62	3,73
	14,13	4,79
Alshamali[19]	12,75	3,8
	14,46	4,83

C. System Responsiveness

In order to use the telehealth system, a web service is created and dedicated URL is being made for each functions. For Tele-ECG system, the URLs available are /RegisterPatient, /RegisterDoctor, /UploadHistory, /LookHistory, /GetDoctorData, /GetHospitalData, /GetUnverifiedHistory, /VerifyHistory, /RegisterHospital, /RegisterAffiliation, and /GetDoctorAffiliation. For Tele-USG system, the URLs available are user/, doctor/, clinic/, officer/, patient/, pregnancy/, photo/, workson/, serve/, comment/, validation/, and photo/usg/.

The average mean response time for Tele-ECG system is 251.3ms. Meanwhile, the average mean response time for Tele-USG system is 45.5ms. Both systems were implemented in different framework. Thus, it explains the gap of the average mean response time for both systems. Tele-ECG system is implemented on JAVA EE framework while Tele-USG system is implemented on Python Django framework.

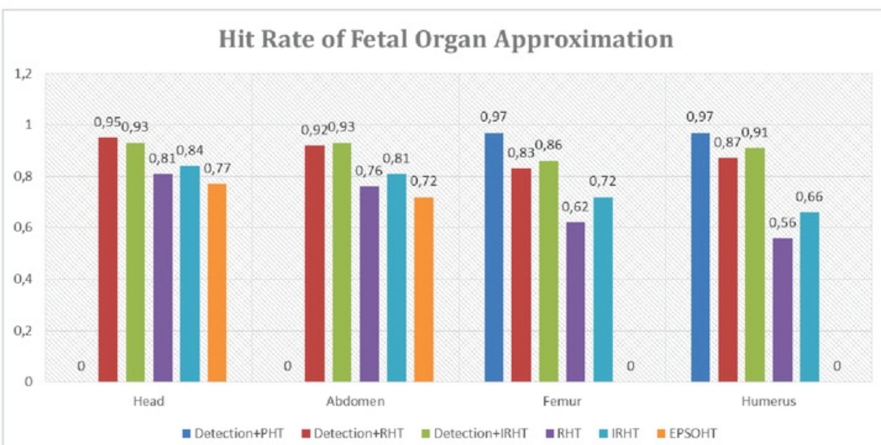

Fig. 9. Tele-USG hit rate

Table 2 Telehealth System Responsiveness

Tele-ECG			Tele-USG		
No	**URL**	**Mean response time (ms)**	**No**	**URL**	**Mean response time (ms)**
1	/RegisterPatient	129,6	1	user/	76,9
2	/RegisterDoctor	218,9	2	doctor/	47,0
3	/UploadHistory	556,4	3	clinic/	29,3
4	/LookHistory	206,6	4	officer/	37,7
5	/GetDoctorData	192,3	5	patient/	29,9
6	/GetHospitalData	231,7	6	pregnancy/	50,2
7	/GetUnverifiedHistory	227,8	7	photo/	36,1
8	/VerifyHistory	160,7	8	workson/	42,8
9	/RegisterHospital	215,0	9	serve/	37,9
10	/RegisterAffiliation	201,8	10	comment/	79,9
11	/GetDoctorAffiliation	423,9	11	validation/	54,6
			12	photo/usg/	23,2
Mean		251,3	Mean		45,5

V. Challenge

A. Sensor Device

For the Tele-USG system, the data is gathered using a USG probe. The USG probe is really complex and very challenging to make by ourselves. In terms of size, the Tele-ECG system is quite large. In the future, we plan to make this device smaller, so it could be more portable and easier to use.

B. System Responsiveness

In Indonesia, the internet connection in remote regions outside of Java is very slow. This is one of the major challenges for us, because our two tele heath devices send images between a patient in a remote region and the doctor in the major cities. We have not yet tested this device outside of the capital region, therefore, we do not know the response and behavior of the system in a remote area.

C. Scurity Issue

As we know, the data and medical record of a patient is highly confidential. Our system have not yet implemented a security encryption for the data. In the next step, we plan to implement an encryption algorithm to protect the patient's data.

D. Big Data

We hope this system is used nationwide, which means we have to prepare the system so it could be used simultaneously by 200 million people. This means that in the near future, we will have to deal with issues of big data so that the system could be optimally used nationwide.

VI. Conclusion

On the Telehealth system, there are several solutions conducted. Firstly, we developed a classifier to automate heartbeat disease prediction with an accuracy of more than 95%, it can be used for early detection. By using this system, we can give advice to patient to prevent worse effects of late treatment. Besides, we also develop a compression method to make transfer data more efficient. It is needed because we know that data from E-Health large enough.

Secondly, we developed a Tele-USG system. Tele-USG system used to detect and approximate a fetus in an ultrasound image. A biometry measurements of the fetus image detection by our system gives a hit rate more than 93%. In the future, we want to implement this system in Indonesia thoroughly, so further research in data management, security for confidential data, and effective communication to transfer Ehealth data will be needed.

References

[1] Sudhamony, S.; Nandakumar, K.; Binu, P.J.; Issac Niwas, S., "Telemedicine and tele-health services for cancer-care delivery in India," in *Communications, IET*, vol.2, no.2, pp.231-236, February 2008

[2] Garawi, S.; Istepanian, R.S.H.; Abu-Rgheff, M.A., "3G wireless communications for mobile robotic tele-ultrasonography systems," in *Csommunications Magazine, IEEE*, vol.44, no.4, pp.91-96, April 2006

[3] Hababeh, I.; Khalil, I.; Khreishah, A., "Designing High Performance Web-Based Computing Services to Promote Telemedicine Database Management System," in *Services Computing, IEEE Transactions on*, vol.8, no.1, pp.47-64, Jan.-Feb. 2015

[4] Imah, Elly Matul, Wisnu Jatmiko, and T. Basaruddin. "Electrocardiogram for Biometrics by using Adaptive Multilayer Generalized Learning Vector Quantization (AMGLVQ): Integrating Feature Extraction and Classification." *International Journal on Smart Sensing and Intelligent Systems* 6 (2013): 1891-1917.

[5] Muhamad Isa, Sani, et al. "Performance Analysis of ECG Signal Compression using SPIHT." *International Journal on Smart Sensing & Intelligent Systems* 6.5 (2013).

[6] Jatmiko, Wisnu, et al. "Automated telehealth system for fetal growth detection and approximation of ultrasound images." *International Journal on Smart Sensing and Intelligent Systems* 8.1 (2015): 697-719.

[7] Ma'sum, M. Anwar, et al. "Automatic Fetal Organs Detection And Approximation In Ultrasound Image." *International Journal on Smart Sensing & Intelligent Systems* 8.1 (2015).

[8] G. D. Clifford, "Baseline wander P. Kultanen, L. Xu, and E. Oja, "Randomized Hough Transform (RHT)," in Pattern Recognition, 1990. Proceedings, 10th International Conference on, vol.1 Jun. 1990, pp. 631–635 vol.1. 2005

[9] W. Lu and J. Tan, "Detection Of Incomplete Ellipse In Imageswith Strong Noise By Iterative Randomized Hough Transform (IRHT)"Pattern Recogn., vol. 41, no. 4, pp. 1268–1279, Apr. 2008

[10] H. D. Cheng, Y. Guo, and Y. Zhang, "A Novel Hough Transform Based on Eliminating Particle Swarm Optimization And Its Applications" PatternRecogn., vol. 42, no. 9, pp. 1959–1969, Sep. 2009

[11] A. L. Goldberger et al., "PhysioBank, PhysioToolkit, and PhysioNet," Circulation, vol. 101, no. 23, p. 215, 2000.

[12] T. Kohonen, "Learning-Vector Quantization and the Self-Organizing Map," in Theory and Applications of Neural Networks, 1992, pp. 235-242

[13] A. Sato and K. Yamada, "Generalized Learning Vector Quantization," in *Advances in Neural Information Processing Systems 8 Proceedings of the 1995 Conference*, 1996, vol. 7, pp. 423-429

[14] Riedmiller, Martin, and Heinrich Braun. "A direct adaptive method for faster backpropagation learning: The RPROP algorithm." *Neural Networks, 1993., IEEE International Conference on*. IEEE, 1993.

[15] Suykens, Johan AK, and Joos Vandewalle. "Least squares support vector machine classifiers." *Neural processing letters* 9.3 (1999): 293-300.

[16] R. Benzid, F. Marir, A. Boussaad, M. Benyoucef, and D. Arar, "Fixed percentage of wavelet coefficients to be zeroed for ECG compression," Electronics Letters, vol. 39, no. 11, p. 830, 2003.

[17] Z. Lu, D. Y. Kim, and W. a Pearlman, "Wavelet compression of ECG signals by the set partitioning in hierarchical trees algorithm.," IEEE transactions on bio-medical engineering, vol. 47, no. 7, pp. 849–56, Jul. 2000

[18] M. Blanco-Velasco, F. Cruz-Roldan, J. I. Godino-Llorente, and K. E. Barner, "ECG compression with retrieved quality guaranteed," vol. 40, no. 23, 2004.

[19] A. Alshamali, T. Ghaith, H. Faculty, and Y. Universitye, "Combined Coding and Adaptive Thresholding Algorithms for ECG Compression," Database, pp. 2–4

Check 21. Developing Smart Telehealth System.pdf

ORIGINALITY REPORT

24%	14%	13%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	docplayer.net Internet Source	10%
2	M. Anwar Ma'sum, Wisnu Jatmiko, Heru Suhartanto. "Enhanced tele ECG system using Hadoop framework to deal with big data processing", 2016 International Workshop on Big Data and Information Security (IWBIS), 2016 Publication	3%
3	Submitted to Universitas Negeri Surabaya The State University of Surabaya Student Paper	2%
4	media.neliti.com Internet Source	2%
5	M. Anwar Ma'sum, Wisnu Jatmiko, M. Iqbal Tawakal, Faris Al Afif. "Automatic fetal organs detection and approximation in ultrasound image using boosting classifier and hough transform", 2014 International Conference on Advanced Computer Science and Information	2%

System, 2014
Publication

6	Wisnu Jatmiko, Dewa Made Sri Arsa, Hanif Wisesa, Grafik Jati, M. Anwar Ma'sum. "A review of big data analytics in the biomedical field", 2016 International Workshop on Big Data and Information Security (IWBIS), 2016 Publication	1%
7	Submitted to Institut Pertanian Bogor Student Paper	1%
8	Wisnu Jatmiko, Ikhsanul Habibie, M. Anwar Ma'sum, Robeth Rahmatullah, I Putu Satwika. "AUTOMATED TELEHEALTH SYSTEM FOR FETAL GROWTH DETECTION AND APPROXIMATION OF ULTRASOUND IMAGES", International Journal on Smart Sensing and Intelligent Systems, 2015 Publication	1%
9	Submitted to BATANGAS STATE UNIVERSITY Student Paper	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		